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Julio A. Gonzalez, Larry G. Berglund, Tom L. Endrusick and Meg, A. Kolka

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Biophysics and Biomedical Modeling Division
U.S. Army Research Institute of Environmental Medicine
Building 42 - Kansas Street
Natick, MA 01760

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The performance of a battery powered, forced air distribution system for ventilation under protective clothing (torso body armor) was evaluated on a sweating thermal manikin in a 35°C and 50% RH environment. The ventilation system, delivering 9 Los-1 of ambient air increased the heat loss from the manikin by 45 W. Measurements made on the manikin indicated that the ventilation decreased the dry thermal resistance and the vapor resistance of the clothing system by 17 and 20 % respectively.

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FORCED VENTILATION OF PROTECTIVE GARMENTS FOR HOT INDUSTRIES

J.A. Gonzalez, L.G. Berglund, T.L. Endrusick*, M.A. Kolka

Biophysics and Biomedical Modeling Division
U.S. Army Research Institute of Environmental Medicine (USARIEM), Natick, MA USA
*corresponding author: thomas.endrusick@us.army.mil

Abstract

The performance of a battery powered, forced air distribution system for ventilation under protective clothing (torso body armor) was evaluated on a sweating thermal manikin in a 35°C and 50% RH environment. The ventilation system, delivering 9 L•s^{-1} of ambient air increased the heat loss from the manikin by 45 W. Measurements made on the manikin indicated that the ventilation decreased the dry thermal resistance and the vapor resistance of the clothing system by 17 and 20 % respectively.

1. Introduction

Heavy protective garments necessary for some industries and military situations insulate the body and reduce body heat loss. In hot environments the garments can impose significant physiological thermal and cardiovascular strains on the wearer. Forced air flow under such heavy protective garments can increase body cooling by improving the evaporation of sweat thereby reducing the physiological strain for the wearer. Without forced ventilation, the sweat secreted under protective garments is often not evaporated and drips off the skin, wasting the cooling potential. Testing with a sweating manikin enables the cooling effect of a forced ventilation system to be evaluated and quantified.

This presentation evaluates the application of a battery powered ventilation system (BVS) for military body armor (BA). The BVS delivered ambient air to a fabric manifold distribution system which encircled the waist and routed the air to a vest attached to the inside of the torso body armor (Figure 1). The fan was located at the lower back waist area.

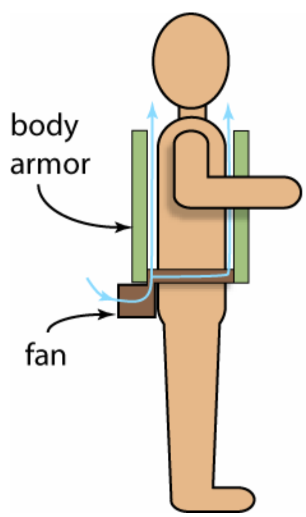

Figure 1. Schematic of ventilation system as worn, side view

2. Methodology

The cooling capacity of the BVS was measured on a sweating thermal manikin according to ASTM F2371[1]. The torso body armor with attached BVS was worn over a Desert Battle Dress Uniform (DBDU). The static manikin was in a climate chamber in a 35°C 50%RH environment with the manikin facing a uniform 0.4 m•s^{-1} wind (Figures 2 and 3). The manikin's surface temperature was controlled to 35°C.

Figure 2. Front view of manikin wearing desert battle dress uniform, body armor with the battery powered BVS standing in the climate chamber.

The ventilation flow rate was determined from the fan inlet area (80 cm^2) and the average intake air speed. The average air speed was calculated from measurements made with a hot bead anemometer over a 12 element grid placed across the inlet area. The calculated inlet flow rate was 9 L•s^{-1}.

The garment cooling capacity with the BVS was determined by measuring the power input to the manikin with the fan OFF and ON. With the fan OFF after the manikin had reached steady state, the power input to the manikin was recorded for 60 minutes. The fan was then turned ON and the manikin was allowed to run until steady state conditions were maintained for two hours. Ventilation cooling was calculated by subtracting the average OFF steady state power average from the average ON steady state power. 120 minutes of power input at steady state were recorded. The test was then repeated a second time.

Figure 3. Rear view of manikin showing the battery powered fan connected to the under armor air distribution system.

The total thermal and vapor resistances of the BVS ensemble were also measured with and without the fan. The total dry thermal resistance was measured on a dry manikin in a 20°C 50%RH environment at wind speeds of 0.4, 1.2 and 2.0 $m \cdot s^{-1}$ following the procedures of ASTM Standard F1291[3]. The total vapor resistance was measured on a sweating thermal manikin in a 35°C 50%RH environment at the same air speeds following the procedures of ASTM Standard F2370[2].

3. Results

The power inputs to the sweating manikin recorded with the ventilation OFF and ON are displayed in Figure 4. Subtracting the average power input with the fan OFF from the average with it ON results in an average cooling capacity of 45.1W associated with the 9 $L \cdot s^{-1}$ of ventilation. Though untested, the cooling capacity would be expected to increase at a lower ambient humidity.

In terms of clothing insulation results, at a wind speed of 1 $m \cdot s^{-1}$ the total dry thermal resistance decreased a nominal 17% and the total vapor resistance decreased by 20% with the BVS fan ON.

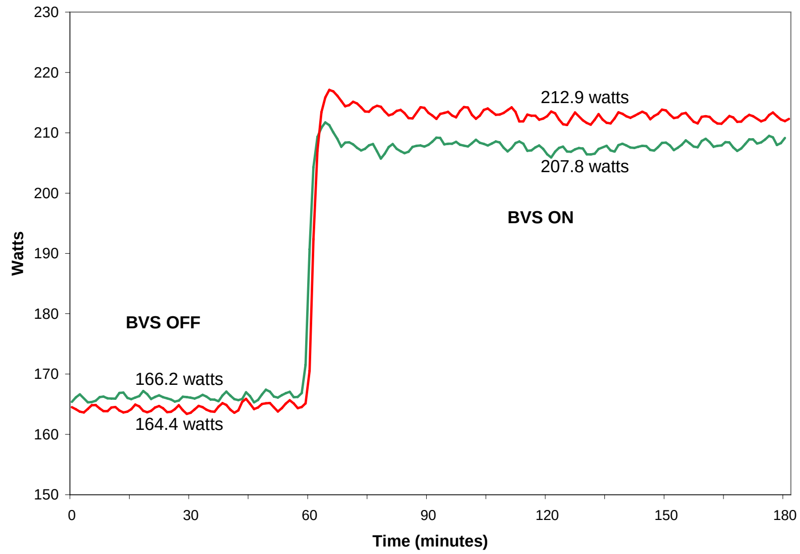

Figure 4. Power input to the sweating manikin with a 35°C surface temperature with ventilation OFF and ON.

4. Conclusions

Forced ventilation under heavy, torso body armor increased the evaporation of sweat and its cooling effect by 45 W. This demonstrates the benefit of clothing ventilation as a simple, economical, light weight method to efficiently improve personal cooling in hot environments. The evaluation of clothing ventilation systems cooling potential and insulation parameters using sweating thermal manikins is accurate, time efficient, very repeatable. In addition manikin testing reduces the cost and health risks of human testing.

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